MRI Motion Detection and Correction with Complex-value AFT-Net

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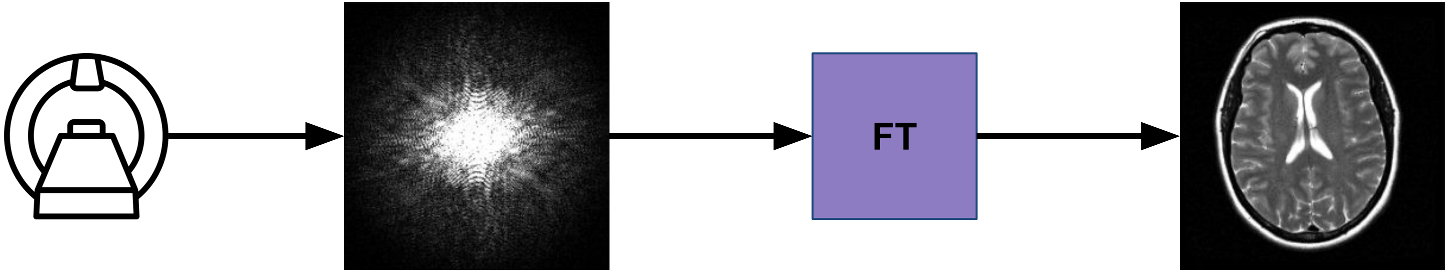
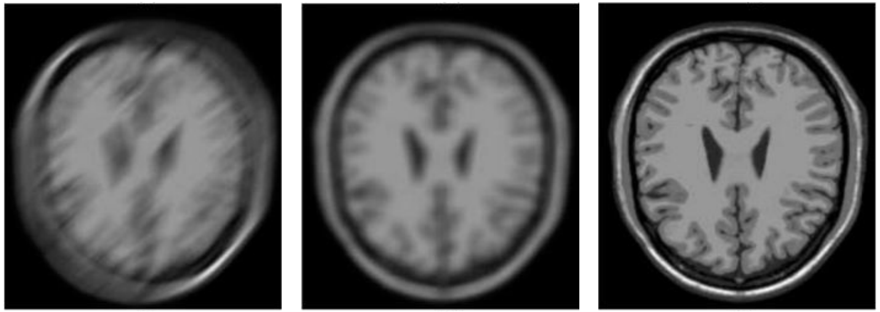
Introduction: Background

- MRI: k-space and image domain



- MRI Motion detection and correction with Deep Learning

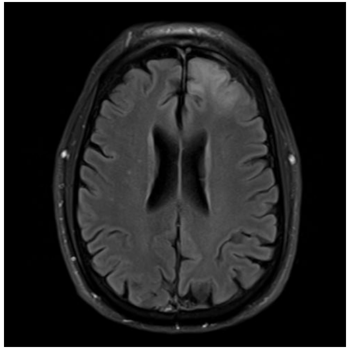


Introduction: Dataset

- Brain MRI: fastMRI Dataset
- 6,970 fully sampled brain MRIs
- 3 & 1.5 Tesla - 4 coils
- Includes axial T1w, T2w and FLAIR images
- Some T1w included admissions of contrast agent

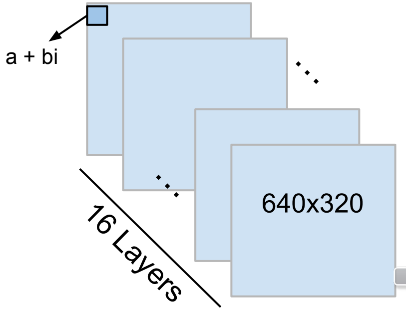
	Type 1	Type 2
acquisition	AXT2	AXT1PRE
slices	16	16
receiverChannels	4	4
height	640	640
weight	320	320
systemFieldStrength_T	1.494	2.8936

Data selection for our project



Type	T2 1.5T	T1 3T	Total
Number	692	109	801

Number of scans for the different contrasts and scanner field strengths of the brain raw dataset selected.



Florian Knoll & Jure Zbontar. fastMRI: A Publicly Available Raw k-Space and DICOM Dataset of Knee Images for Accelerated MR Image Reconstruction Using Machine Learning

Introduction: Existing Research

Deep Learning-based MRI Reconstruction with Artificial Fourier Transform (AFT)-Net

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CU-Net: A Completely Complex U-Net for MR k-space Signal Processing

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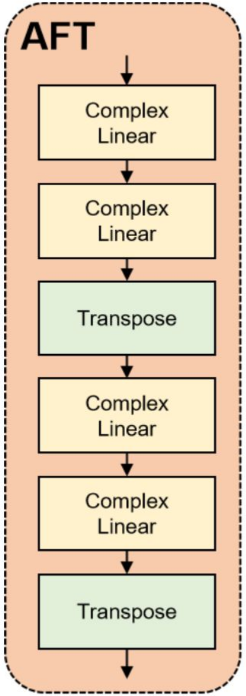
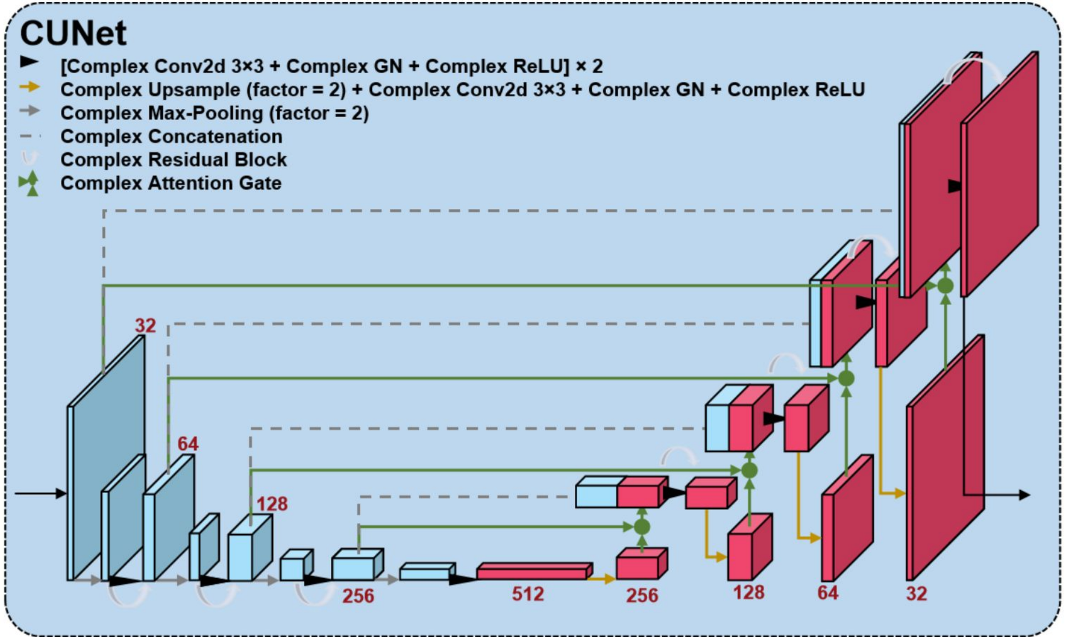
Methods: AFT-Net Architecture





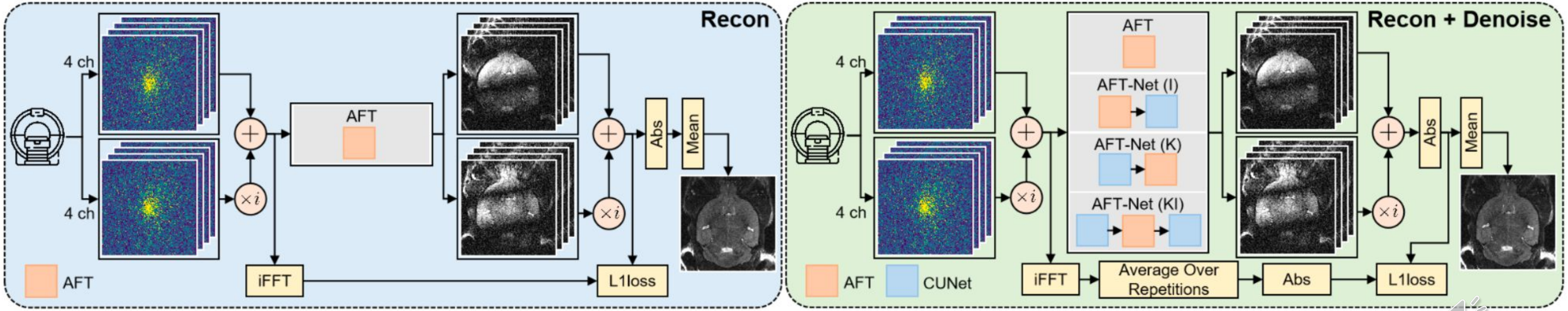
Methods: Previous Experiments

Different flavors of AFT-Net:

- AFT + CUNet = AFT-Net (I)
- CUNet + AFT = AFT-Net (K)
- CUNet + AFT + CUNet = AFT-Net (KI)

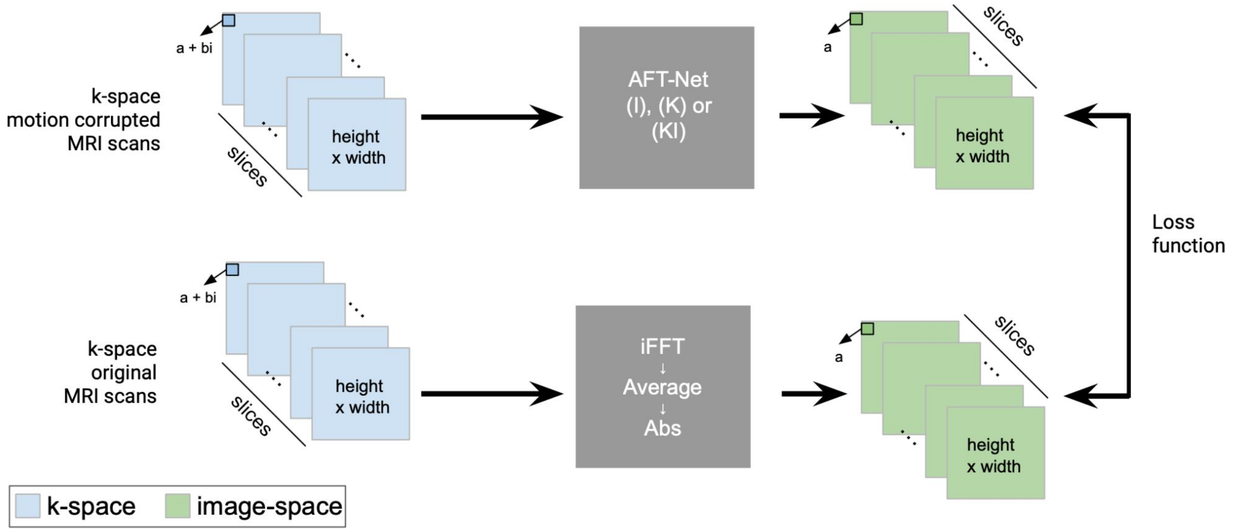
Tasks:

- Reconstruction (AFT only)
- Reconstruction + denoising
- Reconstruction + accelerated imaging



Methods: Our Aims

- Apply AFT-Net for motion correction with human brain data:
  a. Create a motion corrupted dataset from our brain MRI data
  b. Test AFT-Net performance on different configurations

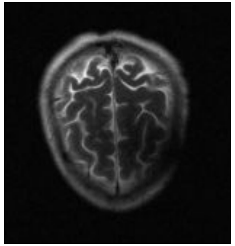


a) Create a motion corrupted dataset from our brain MRI

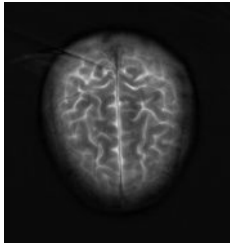
- Goal: add motion artefacts to motion-free k-space data
- Problem: TorchIO package do not take phase information into account, taking the magnitude of the image space data
- Solution: Modified original TorchIO ‘random motion’ class to process raw complex images

TorchIO

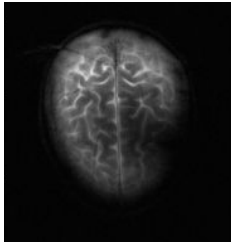
Default image



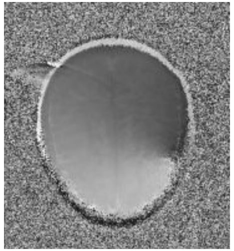
TorchIO corrupted



Modified TorchIO



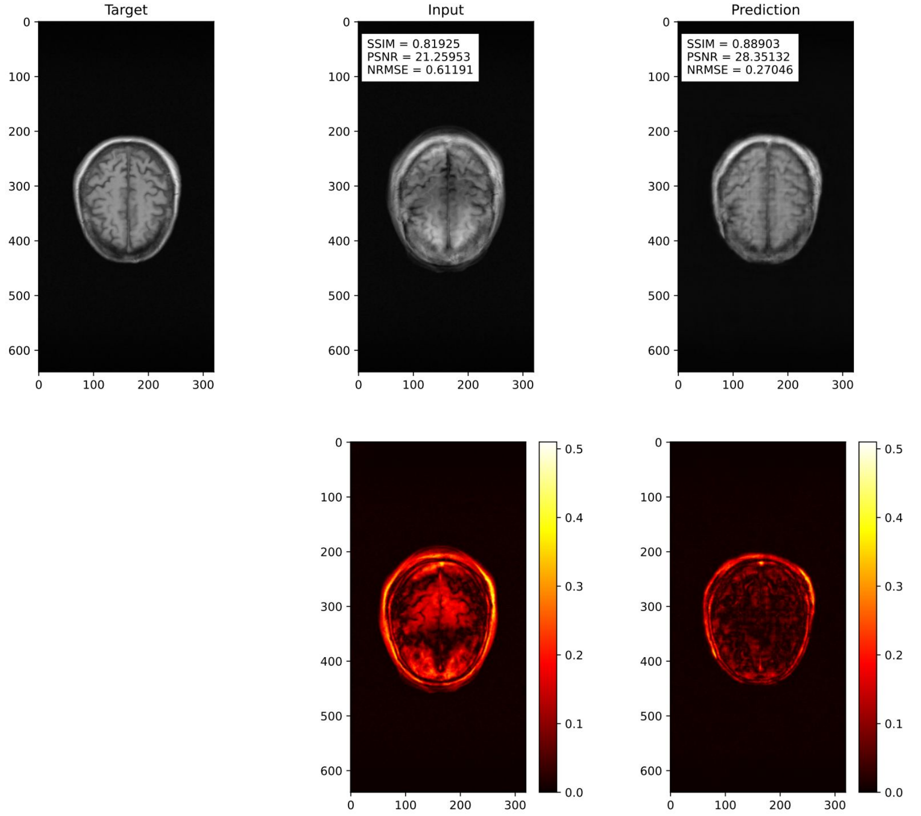
Phase - Modified TorchIO



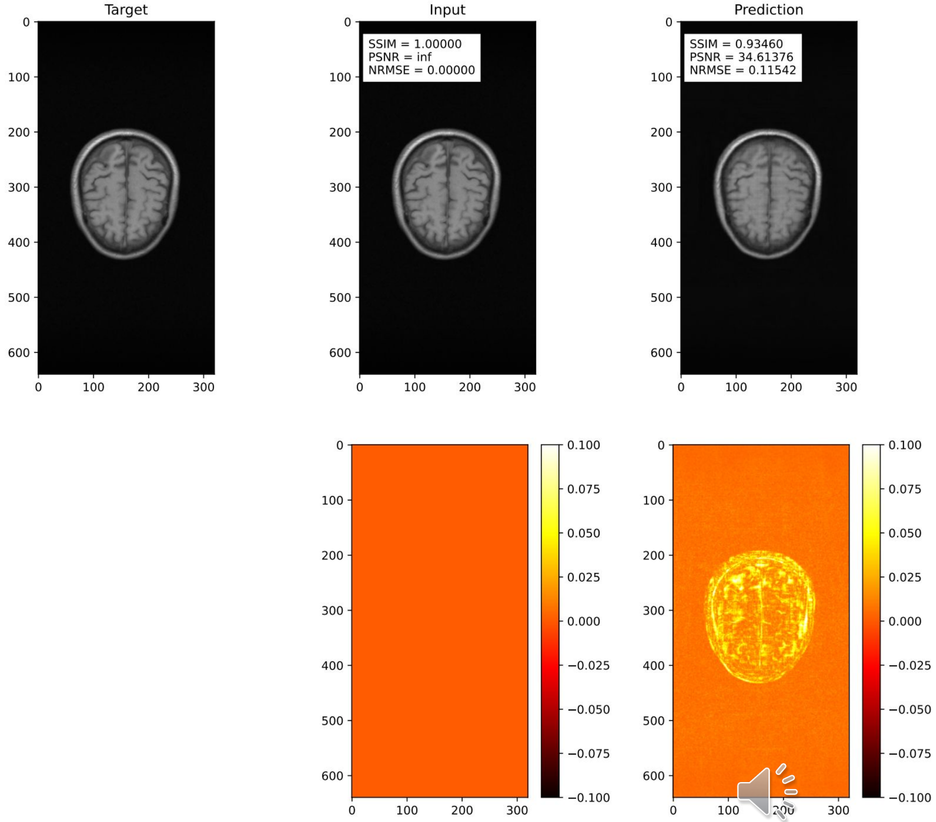
b) Test AFT-Net performance on different configurations

- **Data Augmentation by 2x**: one random motion corrupted image for each image of the dataset
- **Data Splitting**: 60/20/20 keeping corrupted and uncorrupted data balanced
- **Training on**:
  - T1 3T data
  - T2 1.5T data
  - T1 3T & T2 1.5T data
- **Architectures Used**: AFT-Net (I), AFT-Net (KI), AFT-Net (K)
  - Transfer learning based on AFT and CU-Net trainings
- **Optimizer**: Adam with decaying learning rate
- **Loss Function**: MSE
- **Validation Score**: SSIM

Results: Examples [T1- 3T]

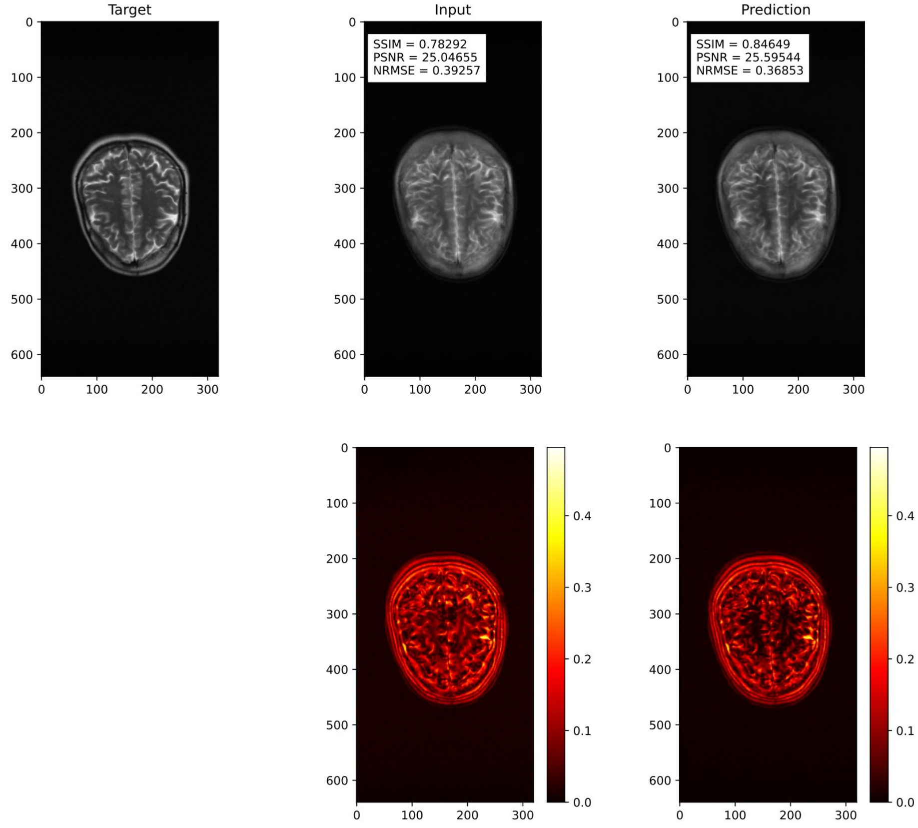


Corrupted image corrected with AFT-Net KI trained on T1 3T only

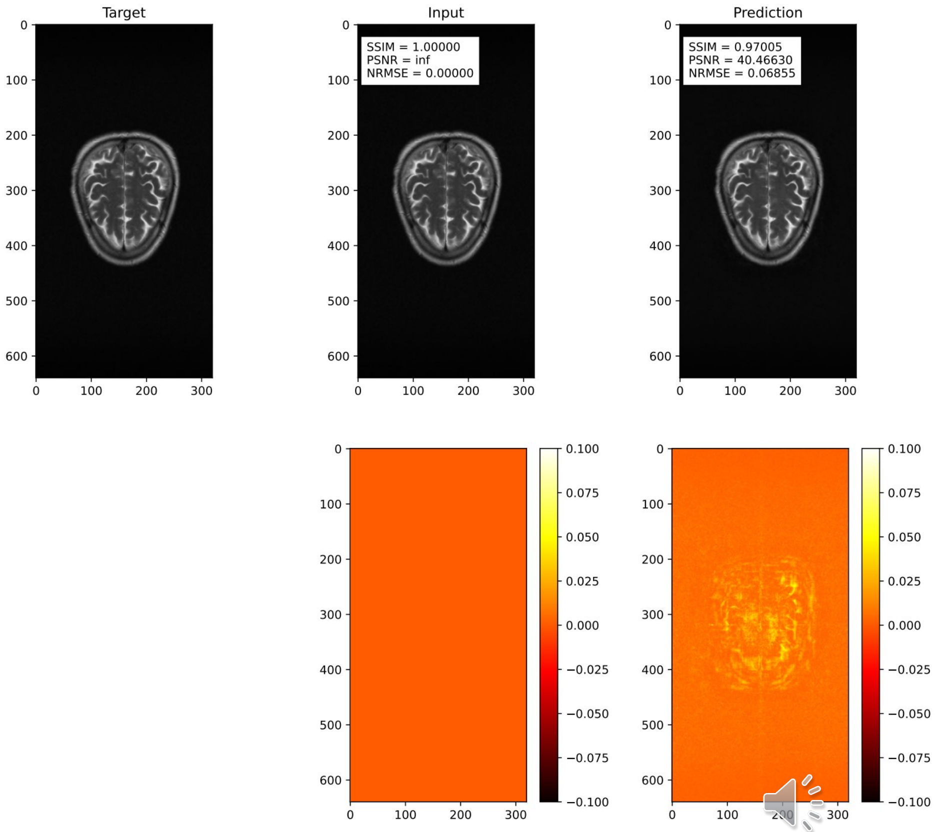


Output of an original image with AFT-Net KI trained on T1 3T only

Results: Examples [T2 - 1.5T]

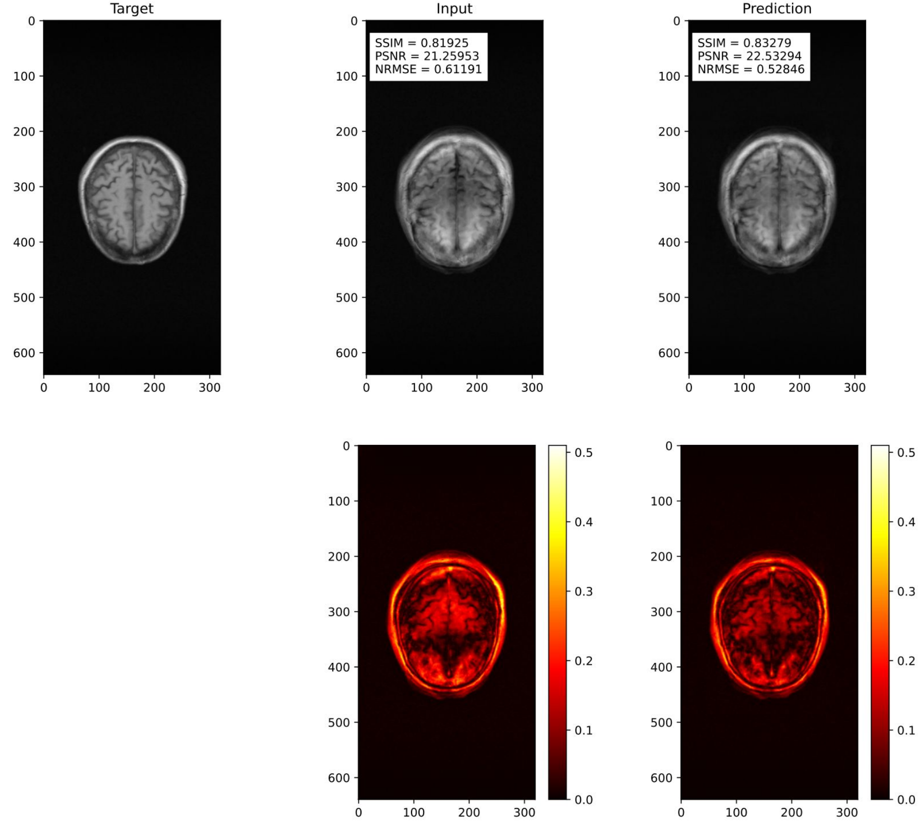


Corrupted image corrected with AFT-Net K trained on T2 1.5T only

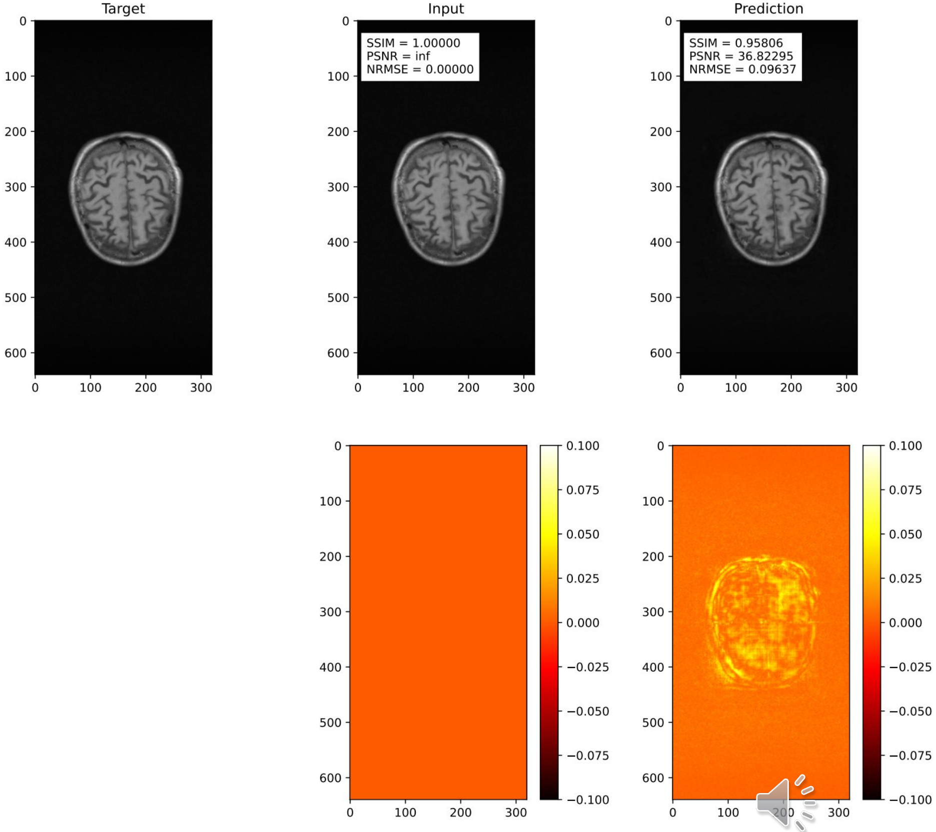


Output of an original image with AFT-Net K trained on T2 1.5T only

Results: Examples [Both Datasets]

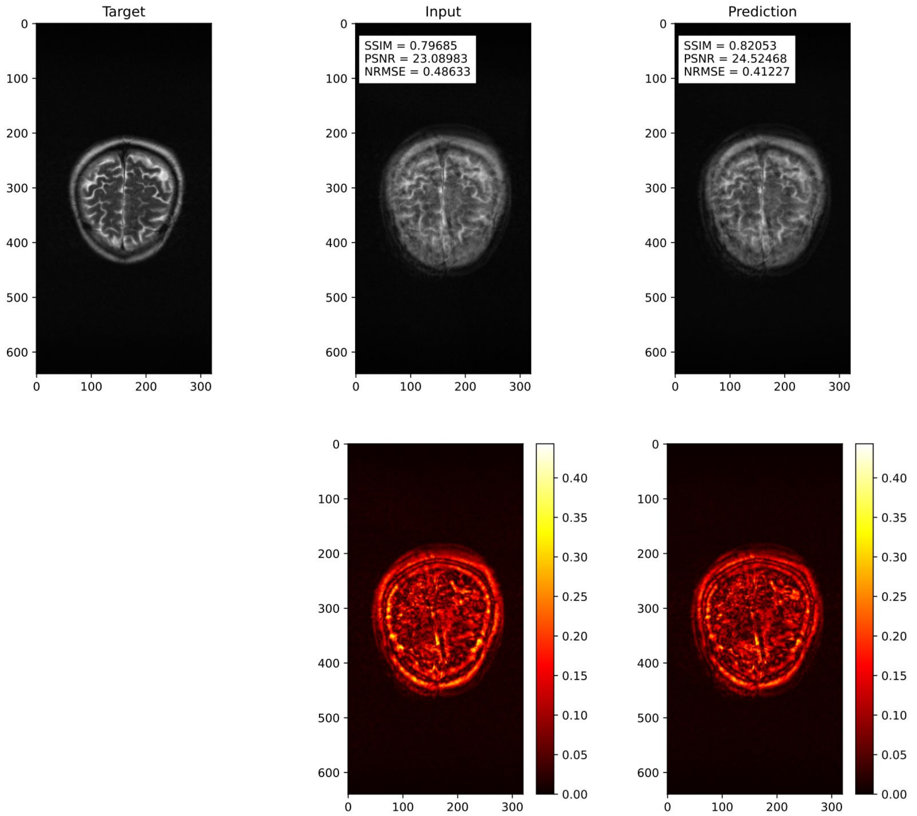


Corrupted T1 image corrected with AFT-Net K trained on both datasets

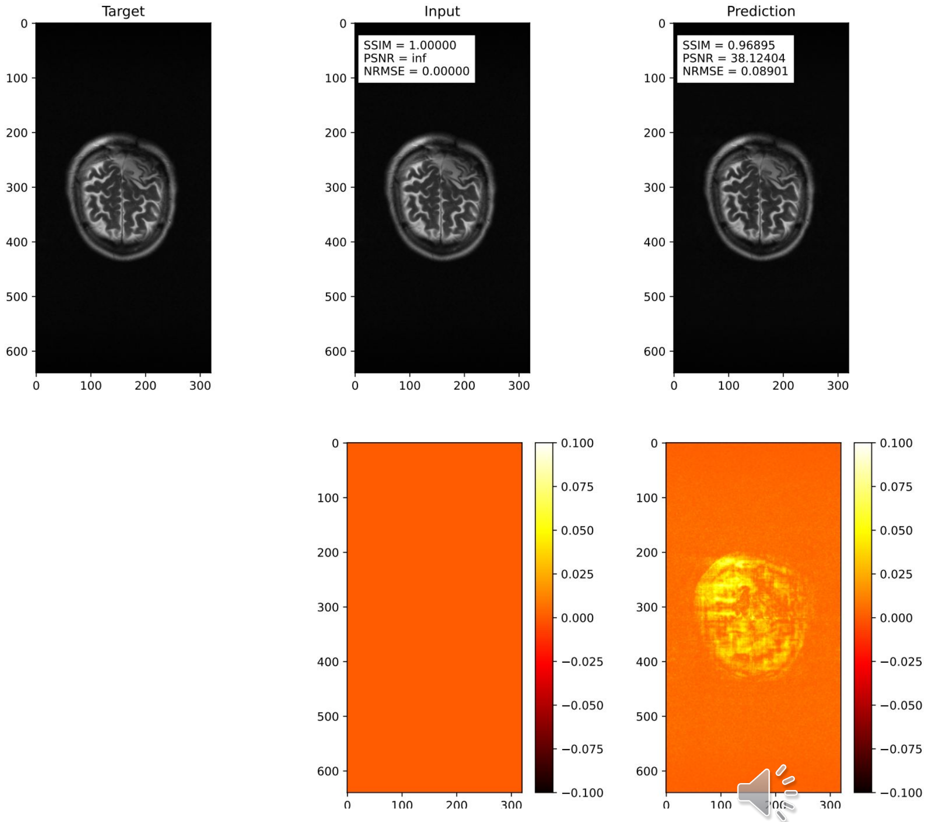


Output of an original T1 image with AFT-Net K trained on on both datasets

Results: Examples [Both Datasets]



Corrupted T2 image corrected with AFT-Net K trained on both datasets



Output of an original T2 image with AFT-Net K trained on on both datasets

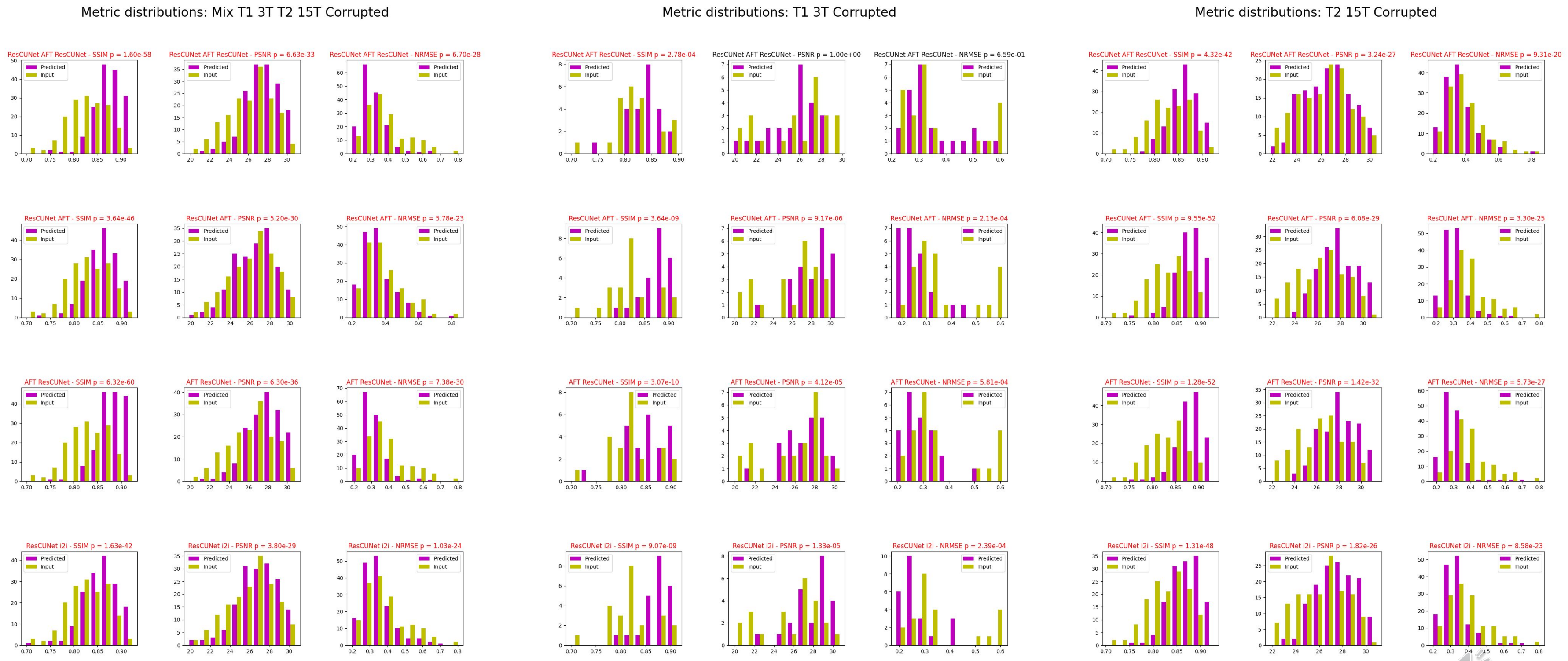
Results: Uncorrupted Data

Dataset	T1 3T			T2 1.5T			T1 3T & T2 1.5T		
Model	SSIM	PSNR	RMSE	SSIM	PSNR	RMSE	SSIM	PSNR	RMSE
CU-Net	9.2102e-01 ± 1.1777e-02	3.2554e+01 ± 1.4513e+00	1.6120e-01 ± 4.0768e-02	9.8498e-01 ± 5.5918e-03	4.3027e+01 ± 1.4326e+00	5.5564e-02 ± 1.4856e-02	9.8000e-01 ± 7.5182e-03	4.1529e+01 ± 1.4636e+00	6.4316e-02 ± 1.4561e-02
I	9.8265e-01 ± 3.7489e-03	3.9668e+01 ± 1.3652e+00	7.0586e-02 ± 1.4042e-02	9.7115e-01 ± 1.6481e-02	4.0101e+01 ± 1.5884e+00	7.8075e-02 ± 2.8748e-02	9.4207e-01 ± 1.4011e-02	3.6691e+01 ± 1.8129e+00	1.1186e-01 ± 2.3939e-02
K	9.2710e-01 ± 1.1893e-02	3.2969e+01 ± 1.9409e+00	1.5702e-01 ± 6.0112e-02	9.4638e-01 ± 2.1725e-02	3.7201e+01 ± 1.7370e+00	1.0886e-01 ± 3.7124e-02	9.6380e-01 ± 1.6273e-02	3.9053e+01 ± 1.4115e+00	8.5600e-02 ± 2.5653e-02
KI	9.0636e-01 ± 1.6601e-02	3.0627e+01 ± 2.0885e+00	2.0840e-01 ± 8.8545e-02	9.6601e-01 ± 1.7412e-02	3.9629e+01 ± 1.3494e+00	8.2621e-02 ± 3.2927e-02	9.5417e-01 ± 2.4976e-02	3.7166e+01 ± 1.9469e+00	1.0789e-01 ± 4.4907e-02

Results: Corrupted Data

Dataset	T1 3T			T2 1.5T			T1 3T & T2 1.5T		
Model	SSIM	PSNR	RMSE	SSIM	PSNR	RMSE	SSIM	PSNR	RMSE
Input	8.1877e-01 ± 4.5789e-02	2.5598e+01 ± 3.1054e+00	3.6372e-01 ± 1.3294e-01	8.2667e-01 ± 4.2110e-02	2.6137e+01 ± 2.1018e+00	3.9201e-01 ± 1.1345e-01	8.2555e-01 ± 4.2741e-02	2.6060e+01 ± 2.2793e+00	3.8799e-01 ± 1.1684e-01
CU-Net	8.7497e-01 ± 2.9343e-02	2.8005e+01 ± 1.9073e+00	2.6742e-01 ± 6.8117e-02	8.7046e-01 ± 3.1495e-02	2.7524e+01 ± 1.6587e+00	3.2917e-01 ± 7.5382e-02	8.5868e-01 ± 3.7086e-02	2.6921e+01 ± 2.0702e+00	3.4798e-01 ± 9.3188e-02
I	8.5325e-01 ± 4.0229e-02	2.7158e+01 ± 2.1591e+00	2.9367e-01 ± 6.8050e-02	8.8594e-01 ± 2.9389e-02	2.8198e+01 ± 1.6451e+00	3.0514e-01 ± 7.4697e-02	8.8092e-01 ± 2.8516e-02	2.7777e+01 ± 1.7843e+00	3.1275e-01 ± 7.2002e-02
K	8.7811e-01 ± 2.7894e-02	2.8252e+01 ± 1.8768e+00	2.6011e-01 ± 6.7219e-02	8.8319e-01 ± 2.7804e-02	2.7924e+01 ± 1.6639e+00	3.1422e-01 ± 7.1508e-02	8.6276e-01 ± 3.2724e-02	2.6586e+01 ± 2.0493e+00	3.6230e-01 ± 9.8917e-02
KI	8.4066e-01 ± 3.0982e-02	2.5598e+01 ± 2.1375e+00	3.5552e-01 ± 1.0082e-01	8.6564e-01 ± 3.0226e-02	2.6650e+01 ± 1.8889e+00	3.6720e-01 ± 9.7826e-02	8.7745e-01 ± 3.0659e-02	2.7587e+01 ± 1.8198e+00	3.2002e-01 ± 7.5657e-02

Results: Statistical Significance



Conclusion & Future Directions

Conclusion:

- Developed a pipeline to simulate motion artefacts on raw k-space MRI scans without losing any information (keeping phase & magnitude)
- Trained AFT-Net on different datasets and with different configurations
- CU-Net and AFT-Net learn features to correct motion artefacts

Future work:

- Test the current architecture on motions only in a 2D space to confirm hypothesis
- Modify this network to handle raw 3D MRI data and create a 3D AFT-Net
- Test on pathological data to see if the model eases diagnosis
- Adapt the training pipeline for pathological data if necessary

Thank you!